# Artificial Intelligence for Robot-Assisted Treatment of Autism

Giuseppe Palestra, Berardina De Carolis, and Floriana Esposito

Department of Computer Science, University of Bari, Bari, Italy giuseppe.palestra@uniba.it

**Abstract.** Designing robot-based treatments for children with Autistic Spectrum Disorder (ASD) is a growing research field. This paper presents an artificial intelligence system based on a robot-assisted treatment of autism. The robot acts as a social mediator, trying to elicit specific behaviors in autistic children. A first preliminary evaluation of the system has been performed involving 3 high functioning children with autism spectrum disorders. The experiments carried out make it possible to evaluate the behavioral response of the children in the eye contact exercise.

Keywords: artificial intelligence, social robots, autism spectrum disorder, eye contact

# 1 Introduction

Autism is a severe disorder of development that is characterized by social interaction/communication difficulties and tendency to engage in repetitive patterns of behavior. A quite large number of early diagnosis and treatment protocols have been designed empirically tested and published in the autism literature. The most recent protocols are derived from Applied Behavior Analyses (ABA) [6] and they have the focus of teaching new skills to autistic children. Artificial intelligence, in particular in robotics, suggests that robots play a promising role to build up the interventions to help autistic children and to cope their impairments related to eye contact, joint attention, imitation, and emotion recognition and production. Several social robots are enable to execute tasks in autistic treatment. Each social robots differs for physical appearance, targeted eliciting behavior, level of autonomy [9]. These characteristics are currently under investigation to understand how and at which extent they influence the treatment. Nevertheless, in the state-of-the-art, significant attention is given to the robot characteristics whereas has not been enough investigated how artificial intelligence can be integrated in traditional autism treatments [10]. A natural robot assisted treatment for ASD children requires to have or simulate intelligent behavior and interaction, based on human speech and body language understanding, emotion recognition and eye contact ability, and other typical intelligent behaviors. In order to build a natural assisted treatment for ASD children a multidisciplinary effort is necessary. Therapists, psychologists, robot developers, and researchers are involved in design robotics treatment protocols for autistic people. The aim of this work is to present an artificial intelligence system based on robot-assisted treatment protocol for autistic children.

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The protocol has been partially used in the SARACEN (Social Assistive Robots for Autistic Children EducatioN) project aimed at developing innovative methods for early diagnosis of ASD and therapy support for autistic children with socially assistive robots. SARACEN has been partially supported by the Italian Ministry for Education, University and Research (MIUR) and by the European Union in the framework of Smart Cities and Communities and Social Innovation of 2007-2013.

This paper is organized as follows. Section 2 reports the state of the art relative to the robot-assisted treatments for autistic children. Section 3 presents an overview of the Artificial Intelligence in Robot-Child Interaction. Section 4 describes the experimental setup and the preliminary results. Finally, conclusions are drawn.

# 2 Related Work

Positive effects of social robots in autistic children treatment are already reported in the literature to elicit specific behavior in ASD children such as emotion generation [8], joint attention and triadic interaction [3], eye contact and social gaze [1]. Many other studies report evidences in the use of social robots in autistic children treatment considering just one aspect at time of the impairment. Barakova and Lourens [2] present three ABA interventions based on NAO robot. The authors analyze the needs and the opportunity for combining artificial intelligence within an application domain such as that of autism. Jarrold [4] proposes a AI-based tutoring system for ASD children that teach mind reading skills. Just some studies take into account more that one aspects of the impairment of ASD children. Zheng et al. [11] present a robot-mediated therapeutic system for imitation skill learning. The system is designed in such a manner that it can operate autonomously or with a therapist depending on the therapy needs. Their study is aimed at drawing attention from the children with ASD and teaching gestures. Palestra et. al [7] present the implementation of an interface for digital PECS therapy that enable ASD people to overcome imitation and motors skills difficulties. None of these studies takes into account all the disabilities of the autistic children during the treatments. An artificial intelligence technology that can deal with several disorders during the treatment is what is missing in the behavioral autism treatment of children.

# **3** Artificial Intelligence in Robot-Child Interaction

The proposed system for ASD treatment includes four main modules: the *RGB-D camera*, the *workstation*, and the *social robot* and the *robot camera*. The overview of the system is illustrated in the figure 1. The child's behavior is captured by two cameras: a 5 mega-pixel auto focus camera on board the robot, and a RGB-D camera. The social robot is the Softbank NAO H25 humanoid robot <sup>1</sup>. NAO has the following technical characteristics:

- 25 degrees of freedom (11 for the lower part and 14 for the upper part);
- x86 AMD GEODE 500MHz CPU with 256 MB of RAM and 2GB of storage;

<sup>&</sup>lt;sup>1</sup> https://www.ald.softbankrobotics.com/en/cool-robots/nao

- Ethernet and Wi-Fi connections.

The workstation is equipped with:

- Intel Core i7-4700MQ CPU (2.40 GHz), with 8GB of RAM;
- 1TB of storage;
- Ubuntu GNU/Linux 16.10 as operating system;

and the following software modules:

- NAOqi API;
- Kinect SDK 2;
- the Robot Intelligence Module (RIM);
- the Behavior Manager (BM).

The workstation uses the NAOqi API to communicate with the robot in order to capture the video streaming from the robot camera and in order to activate specific robot behaviors. The Kinect SDK 2 installed on the workstation is used to acquire depth streaming from the RGB-D camera. The video and depth frames acquired via the sensors are then sent to the RIM. This is composed by four software components: head pose, body posture, eye contact, and facial expression. Each module use specific computer vision algorithms. The RIM detects the child's non verbal signals and transfer them to the BM. In this module is implemented the treatment protocol. A log file in the BM reports an anonymous code for the child, the behavior performed from the robot, the behavioral response of the child, and the exercise performed by the social robot.



**Fig. 1.** Artificial Intelligence System for Robot-Assisted Treatment of Autism. The schema shows how the child-robot interaction loop and the software modules used by the robot to interact with the child: the Robot Intelligent Module (RIM) and the Behavior Manager (BM). The RIM is composed of 4 components: head pose, body posture, eye contact, and facial expression. The BM consist of two components: the treatment protocol and the NAOqi API.

#### 3.1 The Robot-Assisted Treatment Protocol

The protocol is designed to improve a difficult behavior for an autistic child. It is based on the ABA program that includes: a stimulus presentation, a behavioral response, and a reinforcement. The new aspect is the presence of a social robot as a partner to perform the treatment. The protocol has five exercises with three levels of difficulty (see figure 2). The exercises focus on: eye contact, joint attention, body imitation, facial imitation, and facial expression imitation. The child has to performs each level for 5 times and when he/she performs the exercise correctly he/she can pass the next level. The therapist can assign each exercise or a set of exercise to a child according the functioning level.



Fig. 2. Robot-Assisted Treatment Protocol. The protocol is composed of four exercises (three levels of difficulty for each exercise).

In this study only the eye contact exercise has been carried out with autistic children. Therefore, only the eye contact exercise is described in this subsection.

### 3.2 Robot-Assisted Eye Contact Exercise

The eye contact exercise is design to improve the eye contact behavior typically reduced in ASD children. This behavior is essential for interpersonal communication [5]. This exercise consists of three levels which differ in terms of stimulus and reinforcement.

**Easy Level** The robot performs the stimulus: call the child by name and it says "Look at me". The robot repeats the stimulus until the child looks the robot (behavioral response). NAO says "Good!" followed by the name of the child and it plays a music when the eye contact occurs (reinforcement).

**Medium Level** In this level, the stimulus is changed: the robot call the child by name and it does not say "Look at me".

Hard Level The robot does not play the music in this level.

#### 3.3 Automatic Eye Contact Detection

A description of the computer vision based algorithm used to implement the eye contact detection is provided in this section. Our algorithm for eye contact detection needs the RGB camera of the robot placed close (max 40 - 50cm.) to the face of the child.

The pipeline of the eye contact detector, illustrated in the figure 3, is composed of 5 steps: eye detection, preprocessing, iris detection, and pupil detection, pupil position.



Fig. 3. Eye Contact Detection Pipeline.

The algorithm takes images from the camera as an input (raw images) and as a first step the eyes are detected using the well-known Viola-Jones detector implemented in OpenCV. Then, in the preprocessing step the right and left eye patches are converted in 8-bit-deep gray-level image and several filters are applied. The filters applied in the preprocessing step are: thresholding, erosion, and morphological gradient. The next step of the pipeline draws the contours of the iris finding the dark part of the eye (iris) from the white background (sclera). Once the location of the iris has been obtained the pupil can be detected by calculating the centroid of the iris. In the final step the eye contact detection is performed. The eye patches are divided in 8x8 sections: if the pupils are in the center of this grid the eye contact occurred (see figure 4) otherwise the child is looking into something else.

# 4 **Experiments**

In this section an assessment of the system is provided analyzing the behavioral responses of the autistic children. The analyze has the following goals:

- 1. test the artificial intelligent system components in a real environment;
- 2. evaluating the behavioral responses elicited of ASD children.

Three children (C1, C2, C3) with a diagnosis of high functioning ASD (age range of 6-13 years) have been involved in this study.



Fig. 4. Eye Contact Detection Example.

#### 4.1 Procedure

According to the ethical guidelines the personal data related to the children have been anonymized so that the individual identity can not be revealed. The parents of the children signed the informed consent, written in Italian (the participants' mother tongue) of which one copy has been kept by the therapists and the other one by the parents of the child. Participants have been asked to perform three sessions (S1, S2, and S3) with the interface. Each child tests the Eye Contact exercise (Easy, Medium, and Hard levels) to achieve the first assessment of the child with the robotic interface. Subsequently, the robotic treatment program will be tailored on the specific needs of the child. Each children played 15 eye contact exercises for each session. A session lasted 20 minutes on average. The experiment was conducted by expert therapist. The children were admitted one at a time in the experimental room. The therapist and the child entered the room together, the child were placed in front of the robot sitting on a chair. Beforehand, all children participated in a familiarization session lasting 10 minutes. Then, the therapist introduced the social robot providing a simple description of it and answer any child's questions. Subsequently, once the children felt comfortable in the presence of the social robot (usually 10 minutes), the first experimental session (S1) under the supervision of the therapist started. In the first session the robot started with the Easy Level of the Eye Contact exercise as detailed in Section 3.1. In the second session the robot started the Medium Level of the same exercise. Finally, the third session start with the Hard Level of the Eye Contact exercise. For each session the robots repeated 15 times the corresponding level. At the end of each session, a debriefing was given to each participant.

#### 4.2 Results

In general, the system was able to operate well in the treatment environment for all the ASD children. To evaluate the behavior of the children during the interaction with the system, the focus was on the number of the eye contact correctly performed (nEC). The system considers 1000 seconds as the maximum time (tMAX) to perform the eye contact.

Table 1. Percentage of the eye contact act for each participant in S1, S2, and S3.

	<b>S</b> 1	S2	S3
C1	73,33	53,33	20,00
C2	66,67	53,33	26,67
C3		60,00	
AVG	73,33	55,55	28,89

With respect to nEC, it has been observed that, in percentage, the eye contact act had an average success rate equal to 73.33% in S1, 55.55% in S2, and 28.89% in S3 as reported in Table 1.

Figure 5 depicts the nEC achieved by each child in S1, S2, and S3.

A first preliminary evaluation of the system has been performed involving 3 high functioning children with autism spectrum disorders. Results were encouraging, analyzing the nEC in the three different sessions. In fact, it is possible to understand in an objective way the level of difficulty of the child involved in the treatment. This measure can be useful to adjust the treatment in the next session with the robot. In the experiment all children are able to perform well the Eye Contact exercise at the easy level, but they need help when they perform the eye contact at the medium level and at the hard level.



**Fig. 5.** Number of the eye contact acts (nEC) grouped by child (C1, C2, C3).S1=Easy level, S2=Medium level, S3=Hard level

### 5 Conclusions and Future Work

In this paper an Artificial Intelligence system for Robot-Child interaction based on a behavioral treatment protocol has been proposed. Results show as a social robot playing the role of mediator can be successful in robot-assisted treatment of autistic children. The same children who involved in this experiment will be interact with the social robot in the same exercises to test the follow up of the treatment. Moreover, investigations including experiments with a larger sample of autistic children that interact with whole protocol (eye contact joint attention, body imitation, facial imitation, and facial expression imitation) will allow us to test the exercises completely.

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